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The Perception of Lethal Risks - Evidence from a Laboratory Experiment[1]

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Abstract: We run a novel experiment to explore the relationship between the perception of real-life risks and the demand for risk reduction. Subjects play a series of loss lotteries in which the odds are matched to the likelihood of lethal events in real life. For each risk, subjects can pay premiums in order to reduce the likelihood of total bankruptcy. Our results show a complex interplay of mortality perception and demand for risk reduction. We observe that perceived annual mortality positively affects the demand for risk reduction. Moreover, we find certain risk characteristics to affect perceived mortality, others to drive the demand for risk reduction, and some to alter both. Our findings suggest that 30 percent of all insurance payments are due to biased perceptions of annual mortality while perfect precaution could lower payments by 45 percent. Implications for risk management policies are discussed.

Keywords: risk perception, lethal risks, experiment, insurance

JEL Codes: C9, D81.

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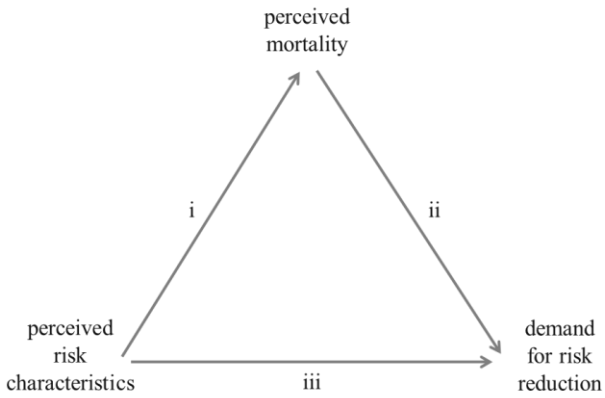
1. Introduction

How do people perceive and respond to lethal risks? How can public risk communication and management be enhanced? During the last decades, a number of studies have raised these and similar questions and contributed to our present understanding of risk perception. One of the most replicated finding is that laypeople form biased expectations about the objective likelihood of lethal events (e.g. Lichtenstein et al. 1978). They underestimate the likelihood of common causes of death and overestimate the likelihood of rare causes of death. Moreover, people's risk perceptions are linked to exogenous anchors such as media coverage or personal experience (Tversky and Kahneman 1974; Lichtenstein et al. 1978). The more often people have been exposed to the consequences of a risk, the higher the perceived levels of risk. Inspired by these early findings, a series of papers has subsequently elaborated what has been labeled as the psychometric approach and analysed the impact of various qualitative characteristics on perceived risk (e.g. Slovic et al. 1980; 1984; Slovic 1987). Overall results suggest that perceived risk is quantifiable and predictable. People's risk judgments seem to be a function of qualitative risk characteristics, such as dreadness, knowledge, controllability or catastrophic potential (Slovic et al. 1980). Newer studies have come to recognize the relevance of emotions beyond psychometric drivers of risk (Sunstein 1997; Loewenstein et al. 2001). They argue that many of the real-world phenomena arise as a result of intuitive reactions to perceived threats. But if people hold both misperceptions about objective mortality rates and preferences to avoid emotionally "bad deaths", should government regulation be aligned to communicational or precautionary measures? More precisely, what exactly drives our desire for risk reduction and perceived mortality?[4] And how do we respond to changes in perceived and actual mortality rates?

In this paper, we present the results of an experimental investigation that provides first answers to these questions. Our study brings real-life risks into the laboratory. It focusses on the demand for risk reduction. In a first step, we analyze how perceived mortality is affected by qualitative risk characteristics (see figure 1). In the second step, we determine the impact of perceived mortality and qualitative characteristics on the demand for risk reduction.

[4] Throughout this study we refer to perceived mortality, subjective mortality (rates), or fatality estimates whenever we refer to people's guesses about the average number of annual deaths that are due to a specific cause.

Figure 1: Demand for risk reduction



Our approach fundamentally differs from previous approaches to risk perception in various ways: First, most studies have focused on the notion of "perceived risk" as dependent variable. That is, subjects are asked to rate a series of hazards according to the risk of dying (e.g. Slovic et al. 1980). While the term "risk" has been fraught with much controversy in the literature (see for example Fischhoff et al. 1984; Sjöberg 1996, 1998; Slovic and Weber 2002), we explicitly focus on the desire to reduce levels of risk. Second, our study relies on revealed rather than expressed preferences. By help of an economic experiment we are able to observe actual behavior rather than hypothetical statements. Third, previous work has mainly focused on links (i) and (iii) of figure 1, the relationship between qualitative risk characteristics and perceived mortality or (presumed) demand for risk reduction. E.g., the lower a hazard's ratings on controllability, the more people may want to see its current risk reduced (Slovic et al. 1984). However, less attention has been devoted to investigating the link between perceived mortality and demand for risk reduction (link (ii)). Fourth, current research largely neglects any kind of (direct or indirect) mediation between qualitative risk characteristics, perceived mortality, and demand for risk reduction. We believe this draws an incomplete picture of the cognitive and emotional reality. Social closeness to victims may bias perceived mortality in a systematic manner, and, at the same time, may also stimulate an individual's willingness to pay for precaution.

We design a novel experiment that allows us to test these interdependencies. Our subjects estimate annual mortality rates and play a series of loss lotteries in which the odds are matched to those of lethal events in real life. For each draw, subjects can buy loss insurances, i.e., they can pay premiums in order to reduce the likelihood of total bankruptcy. Our results show a complex interplay of annual mortality perception and demand for risk reduction. We

observe that qualitative characteristics of risks largely influence levels of perceived mortality and that mortality estimates, in turn, significantly affect the willingness to pay for risk reduction. More importantly, we find certain risk characteristics exerting a direct, unmediated influence on the demand for risk reduction while others exert only an indirect impact mediated by perceived mortality. On the aggregate level we find that 30 percent of all insurance decisions are due to biased perceptions of annual mortality. Living in a world without deadly risks, however, would lower insurance decisions by 45 percent on average. We discuss possible implications for drafting counter-policies.

The remainder of this paper is organized as follows: section 2 summarizes previous research on risk perception. Section 3 presents the experimental design, procedures and theoretical predictions. The results are illustrated and discussed in section 4. The study ends with some concluding remarks in section 5.

2. Perception of lethal risks

Lichtenstein et al. (1978) were among the first who systematically studied how people evaluate lethal events.[5] They ask subjects to judge the frequency of death from various causes. Their subjects exhibit general competence in risk judgments. True frequencies and estimates strongly correlate. However, the authors also identify two kinds of judgment biases: First, the incidence of rare causes of death is considerably overestimated while the incidence of common causes of death is underestimated. Second, statistically identical causes of death can be perceived extremely different depending on previous anchoring. The authors argue that such anchoring effects are due to unrepresentative media coverage and exposure levels, or to a lethal event's vividness. In a series of papers, Slovic et al. (1980; 1981; 1984) delve deeper into the psychological foundations of risk perception. They hypothesize that a large part of the variance in risk judgments can be explained by qualitative risk characteristics. The authors ask subjects to evaluate hazardous activities and technologies regarding a set of risk characteristics. Perceived risk seems to be quantifiable and predictable. I.e., laypeople's judgments of risks are affected by qualitative characteristics of these risks, such as dreadness, knowledge, controllability and catastrophic potential (Slovic et al. 1982).

Slovic et al. (1985) analyze the relationship between risk characteristics, perceived risk, and desired risk reduction. Their subjects are asked how much they want to see strict regulation employed by regulative authorities in order to reduce present levels of risk. Their findings

[5] For overviews on risk perception research see e.g. Slovic et al. (1984), Sjöberg (2000a), or Slovic and Weber (2002).

reveal a huge impact of a risk's dreadness. The higher a risk's scores on this item, the higher the perceived risk, and the higher the desire for risk reduction among subjects. Societal and personal exposure also slightly correlates with perceived risk and desired risk reduction. Sjöberg (1998) asks why people demand reductions in risk. In a series of large scale studies he observes that levels of perceived risk strongly correlate with probabilities of harm or injury. On the other hand, the demand for risk reduction is significantly driven by the severity of consequences.

Gregory and Mendelsohn (1993) use more sophisticated econometric techniques to reassess the data of Slovic et al. They regress nine risk characteristics upon the dependent variables dread and perceived risk. Their analysis corroborates some of Slovic et al.'s findings. Expected effects on future generations, immediacy, equity, and catastrophic potential affect subjects' perceptions of risk and dreadness. Moreover, they find that mortality rates correlate with perceived risk ratings. Benjamin and Dougan (1997) raise some methodological shortcomings in Lichtenstein et al. (1978)'s early work. They criticize that Lichtenstein et al. compare individual risk estimates against population-wide death rates disregarding other variables, in particular, the respondent's age and implications of scarce information. They reestimate the original data correcting for age cohorts and costly information and find strong support in favor of unbiased perceptions of risk. Sjöberg (2000a) runs a series of analyses and finds psychometric characteristics to account for some 20% of the variance in perceived risk. Adding new categories for "unnatural" and "immoral risks" significantly improves the model fit. Moreover, Dohmen et al. (2010) observe that an individual's general attitude towards risk is also a strong predictor of risk taking behavior in the real-world.

Andersson and Lundborg (2007) focus more closely on aspects of self-perception in own risk assessments. They ask their respondents to judge own road-traffic and overall mortality risks and compare these judgments with statistical data available for the respondents' peers. The authors observe a systematic self-perception bias with respect to the overall risk assessment. Subjects generally tend to underestimate their own mortality risk. Similarly, Sjöberg (2000a) reports substantial differences in risk judgments between personal and family risk from a representative survey among the Swedish population.

Table 1: Summary of previous studies

study	investigated correlation	important driver(s)	elicitation method
Lichtenstein et al. (1978)	perceived mortality ↔ qualitative characteristics	objective mortality frequencies, common vs. rare causes, media and personal exposure, event's vividness	expressed
Slovic et al. (1980; 1981; 1984)	perceived risk ↔ qualitative characteristics	dreadness, knowledge, controllability, catastrophic potential	expressed
Slovic et al. (1985)	perceived risk ↔ qualitative characteristics, demand for risk reduction ↔ perceived risk	dreadness, societal and personal exposure dreadness, certainty to be fatal, perceived risk	expressed
Sjöberg (1998)	perceived risk ↔ qualitative characteristics, demand for risk reduction ↔ perceived risk	probabilities of harm or injury severity of consequences	expressed
Gregory and Mendelsohn (1993)	perceived risk ↔ qualitative characteristics, dread risk ↔ qualitative characteristics	expected mortality, effects on future generations, immediacy, catastrophic potential, equity effects on future generations, immediacy, catastrophic potential, equity	expressed
Benjamin and Dougan (1997)	perceived mortality ↔ qualitative characteristics	age, costly information	expressed
Sjöberg (2000a)	perceived risk ↔ qualitative characteristics	unnatural, immoral, personal vs. family	expressed
Dohmen et al. (2010)	lottery decision ↔ individual characteristics	general risk attitude	revealed
Andersson and Lundborg (2007)	perceived mortality ↔ individual characteristics	own mortality	expressed
Johnson et al. (1993)	willingness to pay for flight insurance ↔ qualitative characteristics	event's vividness	expressed
Sunstein (1997)	death equivalents ↔ qualitative characteristics	dreadness, controllability, voluntariness, distributional inequity	expressed
Chanel and Chichilinsky (2009)	lottery decision with heavy personal consequences ↔ qualitative characteristics	fear, catastrophic events	expressed
Loewenstein et al. (2001)	series of statements and decisions ↔ qualitative characteristics	mental imagination (stimulated by an event's vividness or personal experience)	expressed / revealed

Johnson et al. (1993) find strong evidence that a lethal event's vividness matters for people's risk perceptions. They ask their respondents to state their (hypothetical) willingness to pay for different kinds of flight insurance policies. They find a higher willingness to pay for insurances covering "death due to any act of terrorism" than for insurances covering "death due to any reason", which is a superset including the first cause of death. Sunstein (1997) summarizes similar evidence and claims that people evaluate death differently. Deaths that are

dreaded or uncontrollable and deaths that incur involuntarily or are distributed inequitably seem to be worse than others.[6] He argues that assessments of lethal risks "incorporate different social judgments about different kinds of death" (Sunstein 1997: 276). If people are willing to pay premiums to avoid bad deaths, authorities should devise additional resources to regulating them. In a similar vein, Chanel and Chichilinsky (2009) study the influence of fear on decision making under risk. They confront subjects with hypothetical scenarios in which they are kidnapped and ask them to state indifference values on detention period and probabilities. Their results suggest that fear affects laboratory decision making. Some subjects excessively focus on catastrophic events. Loewenstein et al. (2001) argue that such inconsistencies arise as a result of intuitive reactions to danger. Drawing on previous research, they show that anticipatory emotions such as fear, anxiety, and dreadness immediately affect behavior beyond the scope of presently known heuristics and biases. In contrast to analytical modes of thinking, anticipatory emotions are less sensitive to the expected consequences or outcomes but largely depend on mental imagination – stimulated by an event's vividness or personal experience.[7]

Table 1 summarizes the investigated correlations and most important previous findings. Our approach fundamentally differs from these approaches: First, many earlier studies have focused on the notion of "perceived risk" as dependent variable. That is, subjects are asked to rate a series of hazards according to the present risk of dying (e.g. Slovic et al. 1980). As has been criticized, people may perceive lethal risks differently simply because they hold different notions of "risk" (see e.g. Fischhoff et al. 1984; Sjöberg 1996, 1998; Slovic and Weber 2002 for discussions). In this study, we investigate an individual's demand for risk reduction and therefore avoid heterogeneous perceptions to affect behavior. Second, in contrast to previous studies our study relies on revealed rather than expressed preferences. We are able to observe actual decision-making in the laboratory rather than hypothetical statements. Third, previous research has mainly focused on correlations between qualitative risk characteristics and perceived mortality or on the link between qualitative characteristics and (presumed) demand for risk reduction. Less attention has been devoted to investigating the link between perceived mortality and demand for risk reduction. In this study, we run a systematic investigation of all three links. Fourth, current research largely neglects any kind of (direct or indirect) mediation

[6] See also Chilton et al. (2006) for a more recent overview of studies related to dread risks.
[7] A similar approach has already been used by Slovic et al. (1979). They ask subjects to describe their mental images of the consequences following a nuclear accident. The idea that mental visualization affects actual beliefs and behavior also plays a major role in social psychology (see e.g. Rosenblatt et al. 1989, or Pyszcynski et al. 2006).

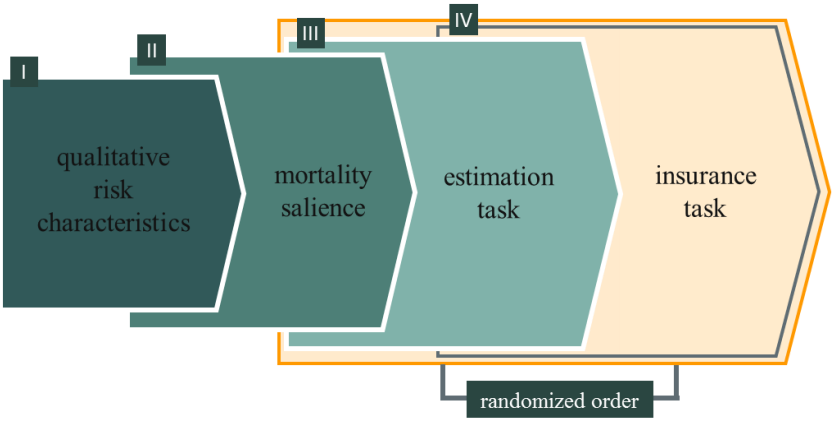
between qualitative risk characteristics, perceived mortality, and the demand for risk reduction. Our analysis incorporates a broad scan on various forms of interdependencies allowing us to estimate the maximum effects of risk communication and governmental precaution on insurance decisions.

3. Experimental design, predictions and procedures

Design

The experiment builds on four phases (see figure 2). At the beginning, subjects are endowed with 20 EUR. Subjects pass through all phases in chronological order except for phases III and IV whose order is randomized.

Figure 2: Sequence of play



During all phases of the experiment we restrict our analysis to the nine real-life risks shown in table 2. These risks can be organized by two dimensions, i.e., the type of death and the average annual death frequency.[8] Each dimension holds three elements: death frequencies p.a. are either relatively "low" (1-5 deaths p.a.), "medium" (300-500 deaths p.a.), or "high" (8.000-10.000 deaths p.a.), while the type of death could be a "violent act", a "disease", or an "accident".[9] The reference group is people living in Germany in the years 2006-2010.[10]

[8] Due to the lack of valid data, we abstained from extending our investigation to "immoral" lethal risks as suggested by Sjöberg (2000a).
[9] See Johnson and Tversky (1984) for similar representations.
[10] Data is available at http://www.gbe-bund.de/.

Table 2: Real-life risks

real-life risk	type of death	deaths (f_i)	mortality	p_{ij} (default)[11]
war	violent act	1.80		0.00
mumps	disease	2.80	low	0.00
commercial plane crash	accident	3.33		0.00
smoke, fire, flames, burning, and scalding	accident	391.20		0.01
HIV/AIDS	disease	458.80	medium	0.01
homicide	violent act	460.60		0.01
accidental falls	accident	8,484.80		0.09
suicide	violent act	9,651.00	high	0.11
stomach cancer	disease	10,468.20		0.11

Phase I is designed to collect information on qualitative risk characteristics (see table 3). First, subjects are asked to state their general willingness to take risks (e.g. Dohmen et al. 2010). Following the psychometric approach, subjects then need to judge each of the nine risks using 7-point rating scales on the most prominent risk characteristics (e.g. Slovic et al 1982). Questions 11-12 are included as to control for an individual's indirect (media) exposure and direct (personal) experience (e.g. Loewenstein et al. 2001).

[11] The values for p_{ij} (default) will be explained below.

Table 3: Risk characteristics and coding[12]

1. general risk
Are you a person that is willing to take risks or do you try to avoid risks?

I am not willing to take risks at all 0 1 2 3 4 5 6 I am completely willing to take risks

2. newness
To what extent is this risk for the society old and familiar or new and novel?

new and novel 0 1 2 3 4 5 6 old and familiar

3. known by science
To what extent is this risk scientifically explored?

fully explored 0 1 2 3 4 5 6 fully unexplored

4. known by exposed
To what extent are people aware of the fact that they are exposed to this risk?

not aware 0 1 2 3 4 5 6 fully aware

5. immediacy
Do you die from the consequences of this risk immediately or is death likely to occur at some later time?

immediately 0 1 2 3 4 5 6 later

6. voluntariness
To what extent do people face this risk voluntarily or involuntarily?

involuntarily 0 1 2 3 4 5 6 voluntarily

7. control
To what extent can you control the probability of death if you are exposed to this risk?

not controllable 0 1 2 3 4 5 6 extremely controllable

8. fatal
When a person is exposed to this risk, how likely is it that this person will die?

highly likely 0 1 2 3 4 5 6 highly unlikely

9. dread
Is this a risk people have great dread for or have they learned to live with it?

great dread 0 1 2 3 4 5 6 no dread

10. catastrophic
Does this risk affect only one person at a time or many people at once?

many people 0 1 2 3 4 5 6 one person

11. indirect exposure (media coverage)
How often have you heard or read about this risk in the media (newspaper, radio, TV, internet)?

often 0 1 2 3 4 5 6 never

12. direct exposure (closeness)
Did you know someone who died by the consequences of this risk?

yes, very close relative or friend 0 1 2 3 4 5 6 no, no one that I know

As previous research on anticipatory emotions suggests, the mental imagination of an event is an important driver of real-world decision making. For that reason, phase II confronts subjects with own mortality. This phase is meant to activate real-world related fears which seem to be less prevalent in normal laboratory environments. Following Rosenblatt et al. (1989), we use two free-form questions and ask our subjects to

[12] We also used reversed coded items to ensure subjects' attention in this phase.

- “jot down, what you think will happen to you as you physically die, and once you are physically dead“ and to
- “[…] briefly describe the emotions that the thought of your own death arouses in you”

before they can proceed to the next phase.

Phases III and IV compass the core elements of the experiment. They are designed to elicit individual data on death estimates (phase III) and willingness to pay for risk reduction (phase IV) for each of the nine risks. Behavior in these phases is negatively incentivized, that is subjects can incur monetary losses.

In phase III, participants have to guess the average number of deaths in Germany during the years 2006-2010 for each of the nine risks and, to account for effects of scarce information, are asked how confident they are about the goodness of their guesses. To simplify the task (and, as a result, to decrease noisiness in individuals’ estimates), subjects are provided with three statistical anchors: first, they are informed about the average number of people living in Germany during the years 2006-2010 (81,471,834). Second, they learn the average numbers of death in these years (841,307). Third, subjects are provided with the average number of people dying from breast cancer during these years (17,339). Total losses of subject j in this phase are determined by the following function:

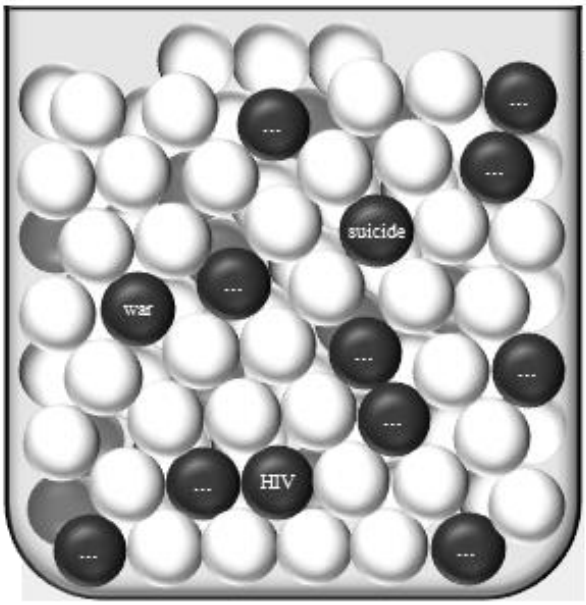
$$\text{total_loss}_{\text{phaseIIIj}} = \sum_{i} \frac{\left|e_{ij} - f_i\right|}{\left|e_{ij} + f_i\right|} \qquad (1)$$

According to equation (1) subjects are punished for bad guesses. The stronger the death estimate, e_{ij}, deviates from a risk’s annual death frequency, f_i (see table 2), the higher the risk-specific loss. Dividing the absolute difference by the absolute sum of estimates and actual numbers normalizes the maximum loss per risk to 1 EUR. The maximum total loss in phase III is therefore limited to 9 EUR.

In phase IV, we use graphical visualization and framing to explain the insurance task. Subjects are instructed to imagine a virtual urn containing 81,471,834 marbles. Each marble would represent an average resident living in Germany at the beginning of an average year. Subjects are informed that there are two types of marbles: 80,630,527 marbles are white. They would represent those people who are still alive at the end of an average year. The remaining 841,307 marbles are black and would represent those people who are expected to die during

an average year. Moreover, each black marble has a small label indicating the corresponding cause of death (see figure 3).

Figure 3: Urn visualization for subjects



white marbles	80,630,527
black marbles	841,307

In the default setting, the computer draws 1,000 marbles without replacement *risk by risk*.[13] If the computer detects (at least) one black marble whose label refers to the presently selected risk, the subject loses all his/her initial endowment of 20 EUR (regardless of their losses in phase III). The original instructions (translated into English) illustrate this procedure in more detail:

> *"You will soon be asked to virtually draw for each of the nine risks from the full urn.* ***Each time, 1,000 marbles without replacement will be drawn****. This number corresponds approximately to the sum of people to which you establish a close relationship during your life (family, friends, colleagues,…). If the computer draws at least one* ***black marble whose label matches the previously specified risk****, you will* ***lose 20 EUR****. This means that, given a specific risk, the probability for losing 20 EUR matches the probability that an arbitrary person of the group of acquainted people will die due to consequences of that risk.*

Moreover, subjects are allowed to manipulate the sample size per drawing. A reduction of 200 marbles costs 1 EUR. For example, if a subject pays 2.50 EUR, the sample size shrinks to 500

[13] We have chosen to use drawings "without" replacement as to align the analytical logic with the experimental framing (see instructions below).

marbles. If a subject pays 5 EUR, the sample size is 0, i.e., there will be no draw at all. On the other hand, no costs are incurred for the default sample size of 1,000 marbles. A translated version of phase IV's decision screen is depicted in figure 4.

Figure 4: Decision screen in phase IV[14]

Formally, each risk-specific loss probability, p_{ij}, follows a hypergeometric probability function that can be described by

$$p_{ij} = \frac{f_i \binom{81{,}471{,}834 - f_i}{1{,}000 - s_{ij} - 1}}{\binom{81{,}471{,}834}{1{,}000 - s_{ij}}} \qquad (2)$$

with f_i as the risk-specific annual fatalities according to table 1 and s_{ij} as the reduction in sample size determined by the subject j. Increasing s_{ij} continuously decreases the loss probability associated with risk i. For example, the default loss probability for stomach cancer is 0.11. The corresponding probability for s_{ij}=500 amounts to 0.06. See table 2 for the default probabilities of the other risks.

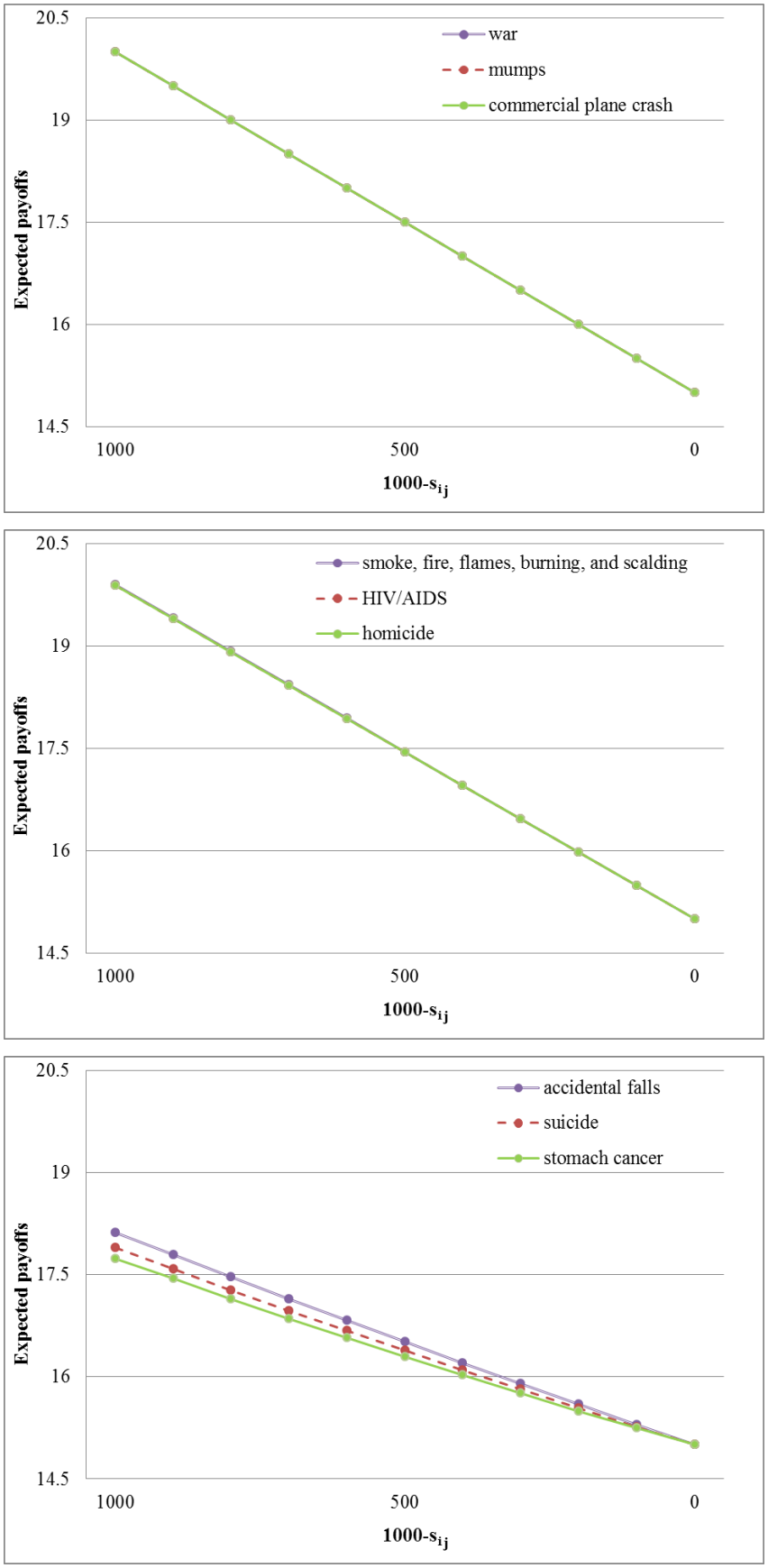
Theoretic predictions

Risk-neutral players will maximize their earnings by comparing expected payoffs across different values for s_{ij}. Figure 5 plots reductions in sample size against expected payoffs for

[14] Programmed in z-Tree (Fischbacher 2007).

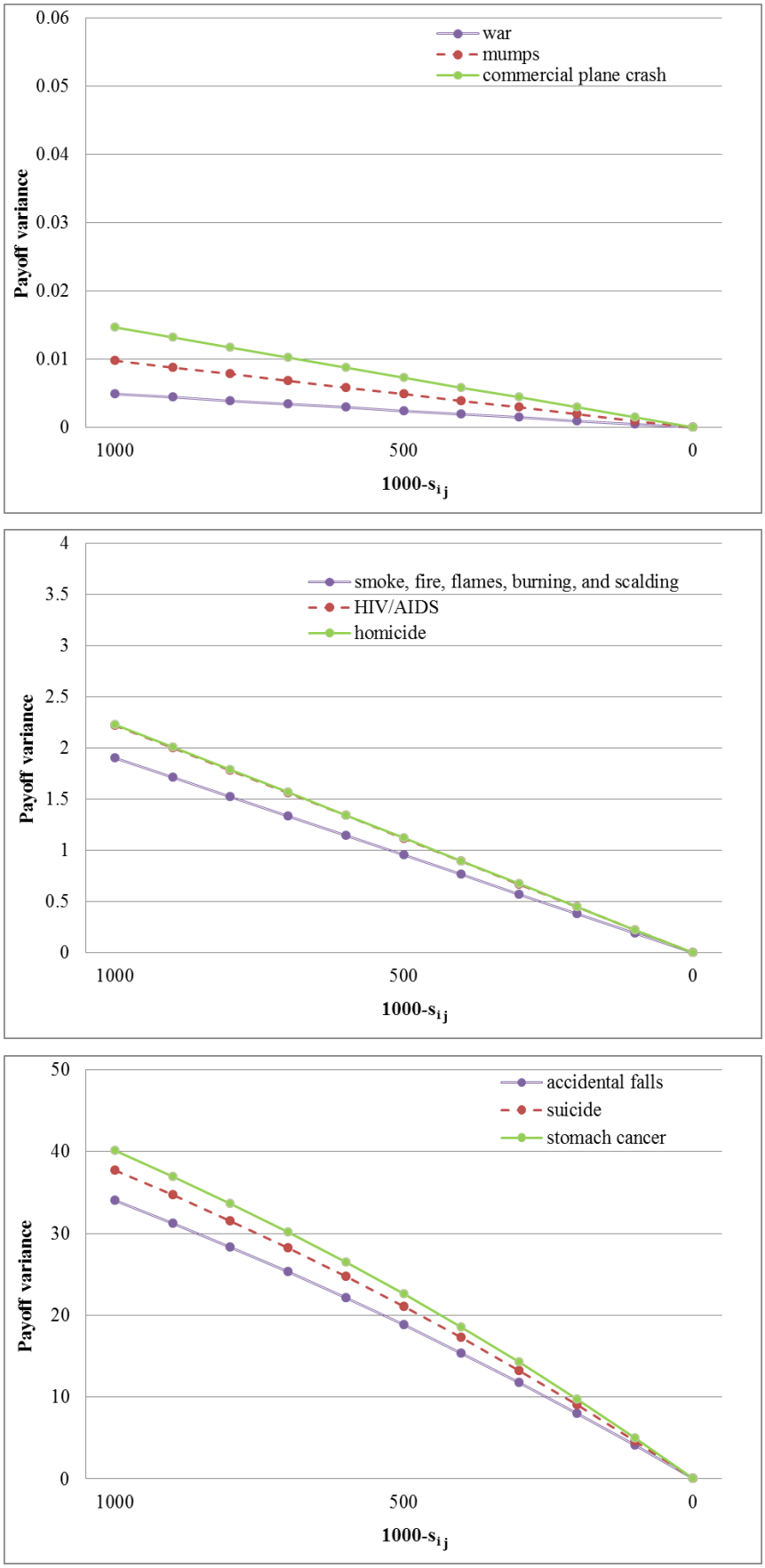
all values of s_{ij} and all types of risk. As can be seen by the negative slopes, setting $s_{ij}=0$ is always a strictly dominant strategy for all risks. Players maximize expected payoffs by playing the default setting disregarding the possibility to reduce the sample size.

Figure 5: Expected payoffs for low, medium, and high mortality risks



However, if players hold risk-averse preferences they may consider the variance in payoffs. They could make their decision dependent on the extent to which payoffs can spread out around the mean value. As can be seen in figure 6, manipulating the default sample size substantially affects payoff variances. The higher the willingness to pay for reductions in the sample size, the lower is the variance in payoffs. That means if subjects have preferences for less risky payoffs, we should observe deviations from the default setting of zero insurance. And, as indicated by the different slopes across low, medium, and high mortality risks, we should find higher s_{ij} and thus lower sample sizes in the (presumably) highest mortality categories.

Figure 6: Payoff variances for low, medium, and high mortality risks



Procedures

The entire experiment was programmed in the experimental software z-tree (Fischbacher 2007) and conducted at the Passau Experimental Laboratory (PAULA). At the beginning of the experiment, subjects were endowed with 20 EUR. In addition, each subject received 2 EUR for showing up on time. Subjects were then informed that they could lose money during the experiment. The accumulated losses in phases III and IV, however, could not exceed the initial endowment of 20 EUR. Throughout the entire experiment, the nine risks were presented in alphabetical order. As to prevent spill-over effects, the psychometric questions in phase I were presented randomly. We also randomized the order in which phases III and IV were played. At the very end of the experiment, standard socio-demographic information was collected. Payoffs were disbursed by a student assistant who was blind to the purpose of the study.

4. Results

Descriptive statistics

We ran five sessions with 93 subjects obtaining a total of 837 risk-specific observations. The average student was 23 years old and studying in his/her third year. 38 percent (35 subjects) were male. This proportion is in line with gender representation at advanced undergraduate levels at the University of Passau. Each session lasted around 30 minutes. Average payoffs were 7.56 EUR for that time with a minimum (maximum) of 2 (16.90) EUR. For comparison, a student assistant at the University of Passau earns 7 EUR per hour. Table 4 reports risk-specific summary statistics for phases III and IV. It depicts types of death, actual deaths p.a., f_i, estimated deaths p.a., e_{ij}, and reductions in sample size, s_{ij}.

Table 4: Real-life risks

real-life risk	type of death	actual deaths, f_i	estimated deaths, e_{ij}	reduction in sample size, s_{ij}
war	violent act	1.80	864.83	73.33
mumps	disease	2.80	2,066.69	36.13
commercial plane crash	accident	3.33	671.53	47.31
smoke, fire, flames, burning, and scalding	accident	391.20	14,036.58	153.87
HIV/AIDS	disease	458.80	13,147.13	149.14
homicide	violent act	460.60	13,972.01	141.51
accidental falls	accident	8,484.80	30,605.42	244.52
suicide	violent act	9,651.00	18,291.71	167.42
stomach cancer	disease	10,468.20	21,896.39	216.34

Similar to Lichtenstein et al. (1978), we observe that subjects have an accurate understanding of real-life risks. Actual numbers of death strongly correlate with individual estimates. However, subjects largely overestimate annual fatalities and relative overestimation decreases in annual deaths. With respect to reductions in sample size, we find substantial deviation from predictions for risk-neutral play. We observe a strong correlation between estimated deaths and the willingness to pay indicating a solid dislike of payoff variance. In total, subjects spend more than 570 EUR for manipulating the default loss probabilities.

With respect to the types of death (accident, disease, or violent act), examining estimated deaths within each mortality category reveals only weak effects. Each of the types ranks lowest once. The medium rank, in contrast, is assigned two times to violent acts, whereas diseases score two times highest. Stronger effects are present when investigating the reductions in sample size. Violent acts seem to induce lower reductions in sample size than diseases, whereas accidents appear to increase the willingness to pay for sample size reductions.

Systematic differences between types of death are also apparent when looking at qualitative risk profiles (figures 7-9). Subjects rate accidents and violent acts to be more familiar and to have more immediate effects than diseases. On the other hand, psychometric rankings of accidents differ from violent acts in terms of perceived dread and likelihood of death. Less distinctive determinants are own awareness and catastrophic potential.

The figures also reveal some variation within types of death. The perception of plane crashes seems to be different from those of other accidents, such as accidental falling or burning. Also HIV seems to slightly differ from perceptions of mumps and stomach cancer. In the category of violent acts, suicide stands out to be different from homicide and war.

Figure 7: Accident risk profiles (mean values)

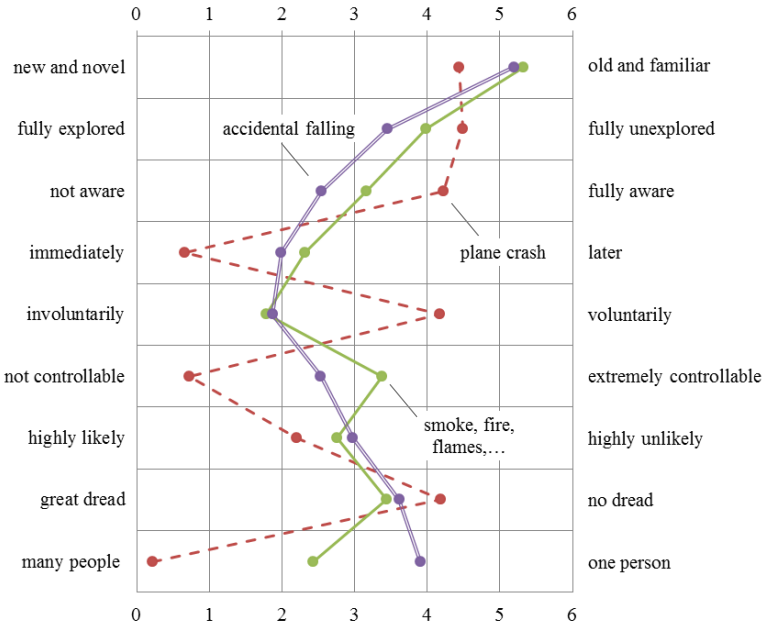


Figure 8: Disease risk profiles (mean values)

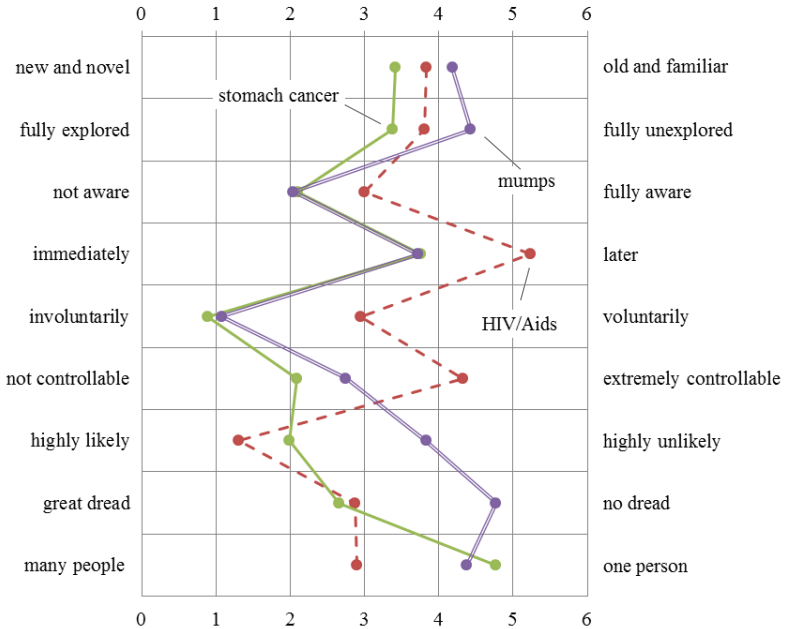
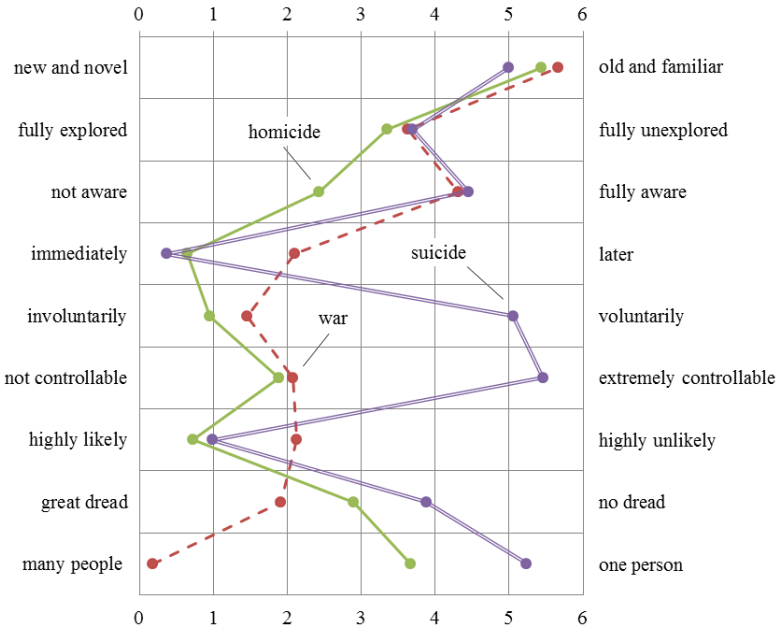


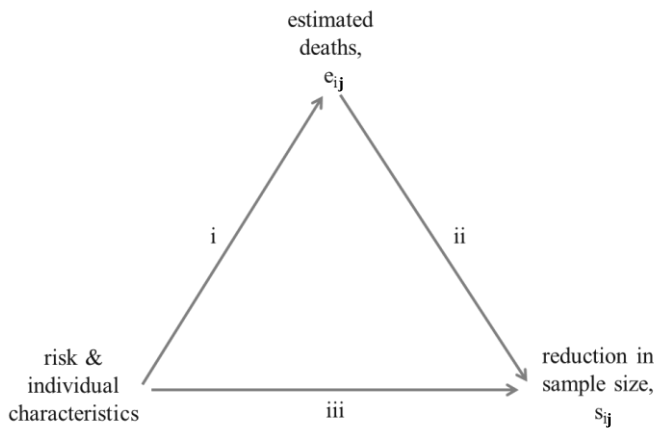
Figure 9: Violent act risk profiles (mean values)



Regression analyses

The descriptive statistics provided some preliminary insights. We will now run a series of OLS regressions to investigate the interdependencies between risk characteristics, perceived mortality, and willingness to pay for risk reduction in more detail. Direct and indirect effects are controlled by estimating a mediation model. Its basic architecture is described by figure 10.

Figure 10: Mediation model



We will start by assessing link (i), the impact of qualitative risk and individual characteristics on the mediator, estimated deaths. In a next step, we will identify the influence of estimated deaths and risk/individual characteristics on reductions in sample size (links (ii) and (iii)). Third, we will determine the set of risk/individual characteristics that are (fully or partially) mediated by estimated deaths.

Table 5 reports the results of seven OLS regressions with cluster robust standard errors.[15] The topmost row captures the dependent variable, either the logarithm of death estimates, e_{ij}, or reductions in sample size, s_{ij}. Models I-III are regressed upon death estimates. Models IV-VII are regressed upon reductions in sample size. The leftmost column lists the explanatory variables: The logarithm of death estimates, e_{ij}, the nine psychometric variables (e.g. Slovic et al. 1982),[16] the controls for indirect (through media coverage) and direct (personal) experience, two dummies for the types of death, and individual characteristics and attitudes.

[15] Our findings are robust to whether using OLS or Tobit regressions.
[16] We abstained from rebuilding Slovic et al.'s factors "dread risk" and "known risk" as partial correlations are not large enough to reach Kaiser-Mayer-Olkin-measures of at least 0,5 for all factors (Kaiser and Rice 1974).

The rightmost column reports the findings of a Sobel-test that will be explained below. Model statistics are reported at the very bottom of table 5.

Table 5: OLS regressions

	estimated deaths, $\log(e_{ij})$			reduction in sample size, s_{ij}				media-tion
	I	II.	III	IV	V	VI.	VII	Sobel p>|t|
estimated deaths, $\log(e_{ij})$				16.77***	14.91***	14.27***		
newness	-0.11	-0.09	-0.10	-3.92	-2.37	-1.39	-2.78	
science	-0.26***	-0.29***	-0.28***	-9.33**	-11.15**	-10.47**	-14.52***	0.01^{p}
exposed	-0.07	-0.05	-0.05	-5.53	-4.45	-4.25	-5.00	
immediacy	0.15**	0.14	0.14	-2.47	-5.59	-4.74	-2.73	
voluntariness	0.00	-0.05	-0.05	2.98	1.27	1.19	0.41	
control	0.19***	0.25***	0.24***	2.15	4.68	4.24	7.73**	0.00^{f}
fatal	-0.13*	-0.22***	-0.22***	2.32	-0.36	-1.04	-4.19	
dread	-0.01	-0.04	-0.05	-10.25**	-11.16**	-11.42**	-12.16**	
catastrophic	0.42***	0.48***	0.47***	2.03	4.27	4.70	11.38***	0.00^{f}
indirect	-0.37***	-0.44***	-0.43***	-8.67	-13.71*	-12.65	-18.73**	0.01^{f}
direct	-0.25**	-0.29**	-0.29**	-23.35***	-25.60***	-26.12***	-30.23***	0.05^{p}
confidence	0.11	0.10	0.11	0.29	0.17	-1.20	0.32	
violent act		-0.80	-0.74		-47.70*	-45.92*	-56.48**	
accident		0.90***	0.94***		11.34	13.54	26.94	
female			-0.31			-8.99	-13.47	
age			-0.06			-6.08***	-6.86***	
general risk			0.11			-4.40	-2.81	
constant	7.65***	7.93***	9.09***	205.30***	248.27***	409.43***	539.14***	
N	837	837	837	837	837	837	837	
R^2	0.22	0.27	0.28	0.18	0.20	0.22	0.17	

Table reports coefficients from OLS regressions with cluster robust standard errors/panels.
Reference for types of death are diseases. *p<0.10, **p<0.05. ***p<0.01.^{f}: full mediation, ^{p}: partial mediation.

Models I-III in table 5 provide evidence on the drivers of death estimates. Generally, estimates seem to be a function of the variables science, immediacy,[17] controllability, fatality, catastrophic potential, and indirect and direct experience. The more delayed the consequences occur, the more controllable a risk is perceived, and the more catastrophic its potential outcome, the higher are stated death estimates. On the other hand, the less is presumably

[17] The influence of immediacy seems to be of rather weak nature as it slightly misses conventional levels of significance in models II and III.

known about a risk, the less likely it is that a person will die from that risk, and the less indirect or direct experience is at hand, the lower the estimated deaths p.a. Confirming the weak preliminary evidence from the descriptive analysis, types of risk also seem to matter. Accidents significantly increase the death estimates compared to diseases. This finding could be the result of excessive risk communication. Subjects may have been repeatedly told that laypeople underestimate the most deadly risks in daily life and have been educated in a way to "correct" for this bias. Other drivers do not play a major role for estimations according to our data. Confidence in the goodness of one's own guess does not seem to affect death estimates. Coefficients of socio-demographic characteristics and the general attitude toward taking risks are insignificant. Also note that, in contrast to many previous findings, individual estimates seem to be invariant to changes in perceived dread.

Models IV-VII investigate the relationship between psychometric and socio-demographic drivers and the willingness to pay for risk reduction. Starting with models IV-VI, we observe a couple of variables exerting a significant influence on the decision to reduce the default sample size in phase IV of the experiment. First, as indicated by the significant constant subjects generally deviate from theoretical predictions and often prefer dominated strategies that are less risky. Second, we find that the coefficient for the logarithm of death estimates significantly differs from zero. The higher an individual's estimate of annual deaths, the higher the willingness to avoid this particular risk. Thus, people do respond to perceived changes in annual deaths (and we also know what drives their perception of annual deaths). Third, if a risk is scientifically unexplored, subjects appear to be less willing to reduce the sample size and, as explained earlier, report lower death estimates. These findings run counter to intuition suggesting that people hold less strongly biased perceptions in the domain of unknown risks. In turn, the more people believe to know about a risk, the more likely they are to overestimate its lethal impact and the more likely they are to insure against losses induced by that risk. Fourth, we are able to replicate earlier studies' findings on perceived dreadness. Dread substantially increases the willingness to pay for risk avoidance. As it does not affect estimated deaths, our data reconfirms Loewenstein et al.'s (2001) argument that anticipatory emotions drive behavior beyond the scope of perceived mortality. Fifth, we observe a significant influence of direct exposure on reductions in sample size.[18] The higher the social distance to victims the lower a subject's reductions in sample size. This extends the prominent

[18] There is also some evidence supporting Lichtenstein et al.'s (1978) conjecture that indirect experience through media coverage increases the willingness to pay for risk avoidance (model V).

view that high exposure levels induce unrepresentativeness biases (e.g. Lichtenstein et al. 1978). Our findings suggest that social closeness also activates the desire for strict regulation beyond actual death frequencies. A similar phenomenon, known as "identifiable victim effect", has already been widely investigated in risk research (Jenni and Loewenstein 1997). However, while the identifiable victim effect explains why people want to see strict regulation employed for others, our data indicate that social closeness also increases the preference for own precaution. Sixth, while the impacts of accidents and diseases do not significantly differ from one another, we observe that violent acts decrease levels of risk avoidance compared to diseases (see models V and VI). This finding is not easy to explain as intuitive characteristics of violent acts such as fatality, dread and indirect/direct exposure are already controlled for. One may argue that our student subjects falsely infer the likelihood of violent deaths from their social environment. However, in this case we would also observe underestimation of death statistics in models II and III. An alternative interpretation could be that subjects put risk premiums on diseases. By reducing the sample size when being confronted with violent acts subjects may then readjust their willingness to pay for risk reduction to its natural level. Seventh, the willingness to reduce the sample size seems to be sensitive to a subject's age. Older subjects in our experiment spend significantly less money on risk avoidance than younger subjects. One may argue that older subjects have learnt to focus more on analytical reasoning than emotional responses. Evidence from Dohmen et al. (2010) contradicts this conjecture. They find strong evidence in a large representative sample suggesting that age negatively affects the willingness to take risks. Given that our sample compasses only 19 observations of subjects older than 25, we have to admit that our finding may be a mere artifact of the student sampling. Other psychometric and socio-demographic variables seem to be less important for risk avoidance.

We have assessed the links (i), (ii), and (iii) of figure 10 and will now turn to the question whether death estimates fully or partially mediate the willingness to reduce the sample size in the insurance task. Generally, mediation is prevalent if an independent variable exerts an indirect influence on the dependent variable that is carried by a third variable, the mediator. The indirect influence evolves from two direct effects: first, the independent variable must significantly affect the mediator (link (i)). Second, the mediator must significantly affect the dependent variable (link (ii)). Moreover, the independent variable is said to be partially mediated if its direct effect on the dependent variable is significantly different from zero (link (iii)). Otherwise, it is fully mediated by the third variable.

In order to determine likely candidates that could be mediated in our data, we first run another regression upon reductions in sample size excluding the mediator (model VII, table 5). Coefficients in model VII capture the total (direct plus indirect) effect of each independent variable on reductions in sample size and allow us to narrow down the set of possible variables being mediated: significant total effects can be found for nine independent variables. These are science, controllability, dreadness, catastrophic potential, indirect/direct experience, violent act, and age. However, according to model III the variables dreadness, violent act, and age do not significantly affect the mediator and can therefore be excluded from further analysis. For the remaining five variables we performed Sobel-tests to determine the significance of the indirect effects. Results are reported in the rightmost column of table 5.

Table 5 provides evidence for three fully mediated variables. The more people can control the probability of death due to a specific risk, the less people are affected by its consequences and the more often people hear about this risk in the media, the higher are the death estimates associated with it, and, in turn, the higher an individual's willingness to pay for risk reduction. We also find two more complex forms of interplay. The variables science and direct experience appear to be partially mediated by death estimates. I.e., the more is known about a risk and the lower the social distance to victims the higher is an individual's death estimate which also increases the willingness to pay for sample size reductions beyond the direct effect exerted by these variables.

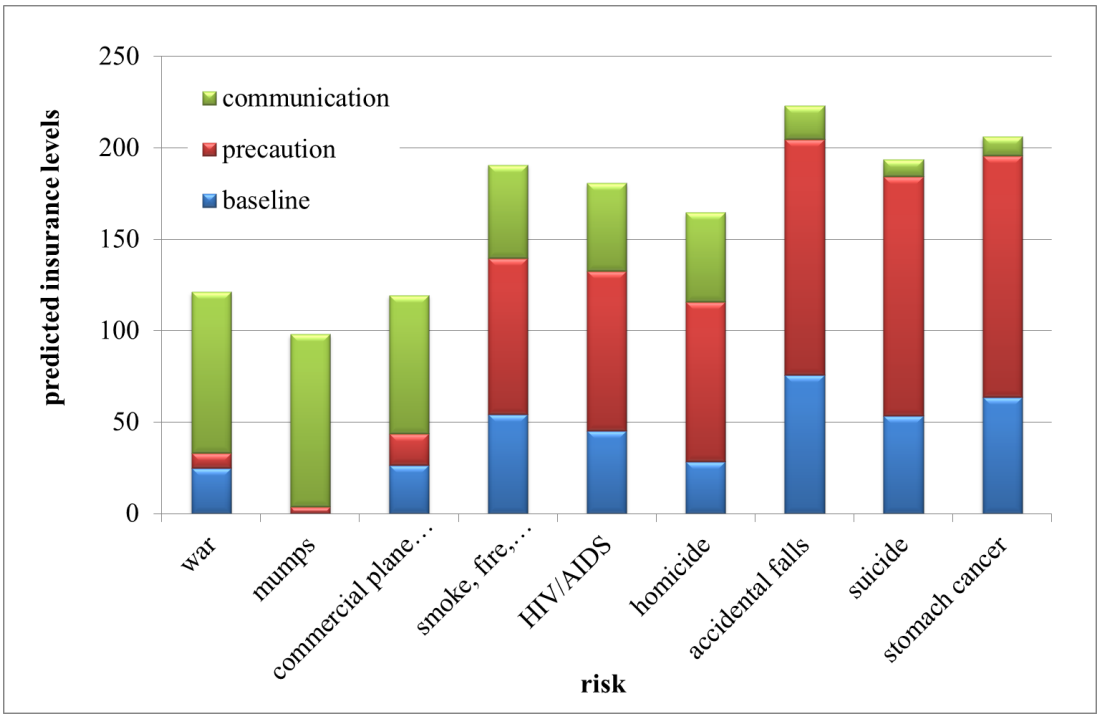
Risk communication versus governmental precaution

The findings of the regression analyses can contribute to the old debate over effective measures of risk management (see e.g. Slovic et al. 1984; Sjöberg 2000b). On the general level, the results suggest that authorities should devise resources to counter biased perceptions if risks score high on variables indirectly affecting insurance behavior. In that case, educational campaigns could de-bias perceptions and satisfy the public desire for safety without reducing actual levels of risk. However, if risks have high scores on variables exerting direct influence authorities should consider precautionary means to reduce current levels of risk. People then want to see strict regulation regardless of actual fatalities and even if this is costly to them.

Nonetheless, the question which technique is more effective in coping with public concerns for safety does not only depend on direct and indirect effects but also on actual and estimated

mortality levels. To illustrate consider figure 11 which shows predicted insurance levels of an average subject for each of the nine risks. The height of each column represents the total reduction in sample size as estimated by model VI of table 5. For example, the average subject is predicted to reduce the default sample size for accidental falls by 244 marbles at a cost of 1.24 EUR.

Figure 11: Predicted insurance levels



The composition of each column demonstrates the relevance of different motives behind insurance decisions. Each column is built on three components – communication, precaution, and baseline. The communication component indicates the maximum effect on insurance decisions that can be induced by risk communication. It shows the amount of marbles that have to be drawn due to biased fatality estimates. Put differently, if all subjects had possessed perfect information about actual fatalities the communication component could be deducted from predicted total insurance levels. The highest potential for risk communication is prevalent in areas of low and medium mortality. In these areas subjects hold relatively

inaccurate perceptions of actual fatalities that strongly drive insurance behavior so that de-biasing may prove to be a powerful tool for risk management. However, considering all nine risks communication seems to have a less extreme impact on insurance decisions. Overall levels could be decreased by around 30 percent if all subjects possessed accurate understandings of annual fatalities.

The second component shows the effect on insurance decisions if precaution is nearly perfect, i.e. if annual fatalities for each risk are reduced to a minimum of 1 dead person p.a. If all risks had been negligible in reality the precaution component could be deducted from predicted insurance levels. In contrast to communication, precautionary means are particularly relevant in the domains of medium and high mortality. The higher actual fatalities p.a. the more subjects want to see the current risks reduced. Moreover, considering the total effect precaution seems to be a quite powerful tool for risk management. Across all nine risks perfect precaution can reduce levels of insurance by around 45 percent.

With the component effects at hand, we can determine the optimal policy responses for each risk. Table 6 shows again the list of nine risks and corresponding threshold values. The threshold values are determined by dividing the relative reductions in predicted insurance induced by communication by the relative reductions in predicted insurance induced by precaution. It hence reflects the relative power ratio between communication and precaution. For example, a threshold value close to 1 suggests that communication and precaution are about equally powerful in coping with a particular risk. If threshold values are below 1, precaution seems to be more powerful and, vice versa, if threshold values are above 1 communication appears to be more powerful than precaution.

Table 6: Risk thresholds

real-life risk	**threshold**
war	10.51
mumps	24.75
commercial plane crash	4.41
smoke, fire, flames, burning, and scalding	0.60
HIV/AIDS	0.55
homicide	0.56
accidental falls	0.14

suicide	0.07
stomach cancer	0.08

The optimal risk policy can be determined by comparing threshold values with actual costs ratios between communication and precaution, i.e. the costs for perfect communication divided by the costs for perfect precaution.[19] If these values lie above the threshold, communication is a less efficient tool than precaution. If the actual costs ratios lie below thresholds risk communication is more efficient. For example, if educational campaigns to de-bias laypersons' perceptions on HIV/AIDS cost less than half of the amount that had to be spent to find a cure for HIV/AIDS, risk communication is the more efficient policy. Analogously, if perfect risk communication becomes almost as expensive as finding a cure, the optimal response is focusing on precaution.

The third component in figure 11 indicates baseline insurance levels. These decisions are solely motivated by specific combinations of risk characteristics and are thus independent of biased death estimates or actual mortality rates. They reflect the premiums that subjects place on particularly bad deaths. As can be seen baseline insurance levels correlate with mortality categories. This finding is somewhat surprising as we have already controlled for the effects of death estimates. Low premiums are assigned to deaths by mumps, plane crashes, and war. Note that the latter is reported to be the most dreaded one of all nine risks. Highest premiums, in contrast, are placed on accidental falls, stomach cancer and smoke, fire, flames, burning, and scalding. These are old and familiar risks that are faced rather involuntarily and affect only a few people. None of these risks is reported to be particularly dreaded. Premiums on these risks may hence be the result of anticipatory emotions that go beyond the cognitive evaluation of perceived dreadness. In early human history, a group's survival may have strongly depended on environmental factors. Over hundreds of generations people may have ingrained affective responses to encounter deaths due to falling, starvation, or burning.

5. Conclusion

In this study, we present a novel experiment to explore the relationship between qualitative risk characteristics, perceived mortality and demand for risk reduction. Our subjects play a series of loss lotteries in which the odds are matched to the likelihood of lethal events in real

[19] Of course, we focus on hypothetical and simplified scenarios in our simulation disregarding uncertainty or any kind of interaction between communication and precaution. However, we believe that such threshold values, once re-estimated for particular programs, provide reasonable rules of thumb for decision-making.

life. For each risk, subjects can pay premiums in order to reduce the likelihood of total bankruptcy.

The results of the experiment confirm that subjects have quite accurate perceptions for some lethal risks, while they exhibit inner reluctance to others. As a novelty, we are able to differentiate between risk characteristics that directly manipulate subjects' perceptions of actual death frequencies and those that directly affect the willingness to pay for risk reduction. We also find the impact of certain characteristics to be partially or fully mediated by perceived mortality. On the aggregate level, we find that 30 percent of all insurance decisions are the result of biased perceptions of annual mortality. Living in an (almost) peaceful world without deadly risks, however, would lower insurance decisions by 45 percent.

Should authorities now invest in de-biasing public perceptions or spend money on precaution? Our results suggest that indirect effects offer effective channels for risk communication while direct effects call public authorities to employ strict regulation. In addition, communicational measures should prove extremely useful in domains with low numbers of annual fatalities. Once fatalities rise, the effect of risk communication becomes less dominant. In these areas, precautionary measures are more powerful tools to satisfy the public desire for risk reduction.

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